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Total Phosphorus and Phytate Phosphorus Content in Grain Maize (*Zea Mays*)

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Abstract

The aim of this work was to analyse the total and phytate phosphorus contents of grain maize varieties from three Central German locations, since these are important factors for the availability of P. For all 100 tested maize samples the total phosphorus content of 3.41 g/kg DM and a phytate phosphorus content of 2.63 g/kg DM and the ratio phytate/total phosphorus of 77 % were determined. Also, it was to be established whether the total and phytate phosphorus contents are influenced by variety, location, climate or maturity group. While a statistically significant influence of varieties on the total and phytate phosphorus contents could not be proved, it was possible to detect statistically significant differences between the total and phytate phosphorus contents among the varieties of the early and medium-early maturity groups. One could notice a statistically significant influence of the location on total phosphorus and phytate phosphorus contents. The crop years had also got a significant influence.

1 Introduction

Maize belongs to the most important cereal varieties for human and animal nutrition. In Germany, for example, 80 % of the maize production is used as feedstuffs (Statistisches Jahrbuch, 1997). In African and American countries maize plays an essential role as food for humans. One important component of maize for animals and humans is phosphorus and energy. However, about 70 % of the total phosphorus in maize is bound as phytate phosphorus. Therefore it is not available for humans and monogastric animals that hardly contain any endogenous phytase and cannot hydrolyse phytate phosphorus in the intestinal tract to reach the sufficient phosphorus supply and thus their optimal level of performance. Phytic acid, which is myoinositol 1,2,3,4,5,6-hexakis (dihydrogen phosphate), does not only interfere with the intestinal absorption of certain minerals, e.g. phosphorus or zinc, but also of protein, and thus causes nutritional deficiencies.

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The bound phosphorus is the reason why inorganic phosphorus must be added. It is important to know the contents of total and phytate phosphorus in different varieties of maize to optimize the addition of inorganic phosphorus or microbial phytase, especially since there have not been any systematic investigations so far. The analyses carried out by Jongbloed and Kemme (1990), Lantzsch (1990), Eeckhout and De Paepe (1994) referred only to small numbers of samples from abroad without describing the tested varieties or locations. MOST et al. (1993) assumed e.g. that the reason for varying values could be found in different methods of selection and analyses. However, there have not been made many systematic experiments concerning variabilities of phosphorus contents caused by variety, season, year or environment.

The aim of this study was to find possible climatic, genetic and local influences as well as effects of maturity group on total and phytate phosphorus in maize which could explain the variability of these values. Grain maize is to be used for the production of dry grain in Central Germany. For this reason appropriate investigations into the phosphorus contents (total and phytate-P) of varietally pure sample material from three locations and two crop years were carried out.

2 Material and Methods

One hundred grain maize samples from 28 varieties grown in central Germany (Saxony) have been chosen to determine their total and phytate phosphorus contents as well as possible influences by variety, maturity group, location and crop year. The selection was taken according to the different parameters (see Tables 1 to 3) like different geographic, climatic conditions and locations. Six grain maize varieties (24 samples) included in this study from two locations were additionally tested in two crop years concerning their phytase activities.

The phosphorus content in soil on three locations (Pommritz, Spröda and Glesien) was analysed and the differences in phosphorus content were balanced with P-fertilization to reach the same level of soil nutrient provision in the soil. Unfortunately, the bad weather conditions at the location Spröda did not allow the inclusion of sample material from there in 1996.

12 early and 15 medium-early varieties from the locations Pommritz and Spröda were chosen for the analysis of the influence of maturity group on total and phytate phosphorus contents in 1995.

2.1 Analytical methods

The content of total phosphorus was analysed according to the methods of VDLUFA (1976/1993). It was measured spectrophotometrically at a wave length of 420 nm (Spectrophotometer Pharmacias "LKB-Ultrospec III") after mineralizing the samples by breaking down and converting it with Molybdat-Vanadat. The phytate phosphorus content was determined according to the AOAC-method (1990) by the exchange of anions. The phytate phosphorus was extracted out of doubled dried samplings with diluted 2.5% hydrochloric acid, mixed with EDTA/NaOH solution and put into an anion-exchange-column.

Phytate was eluted with 0.7 mol NaCl and broken down by a mixture of concentrated HNO_3/ H_2SO_4 to determine the total-P calorimetrically. The phytase activity was measured following the method described by VDLUFA (1997). The enzyme phytase was mixed with Na-phytate and developed inorganic phytate from their substratum. The addition of acidic Molybdat-Vanadat reagent stopped the incubation and a coloured complex developed with the phosphate.

2.2 *Statistical analysis*

The evaluations of the results as analyses of the variance were made with the help of the programme Statistica for Windows ™ (Version 5.0, Stat. Soft. INC. 1995). For the multiple analysis of the variance the Tukey-HSD-Test has been used, while simple comparisons of mean values were made by the t-Test. Significant effects or interactions are shown in the tables by the p-value (level of significance: *=p<0.05; **=p<0.01; ***p<0.001; ns = not significant). Different letters within one column indicate significant differences of the mean values. The standard deviation (±) is also given in the tables. The relation between two parameters is calculated by correlation (correlation coefficient = r).

Table 1: Characteristics of the tested locations

Location	Soil	Valuation index of field	Height above sea-level (m)	P_2O_5 content (mg/100g soil)	Soil nutrient provision	pH-value
Pommritz	loam-sandy loam	61	230	26	C	6.7
Spröda	Loamy sand	30	120	11	B	5.9
Glesien	loam-sandy loam	62	127	24	C	6.1

Table 2: Climatic conditions in the crop years (1995 and 1996)[1]

Location	Average precipitation (mm)			Average temperature (°C)		
	long-term average[1]	1995	1996	long-term average[1]	1995	1996
Pommritz	349	523	461	15.8	15.5	14.7
Spröda	286	257	-	16.4	16.4	-
Glesien	283	347	240	15.5	16.4	14.8

[1]May - September [2]Over 10 years

Table 3: Analysed grain maize sample material[1]

	Locations in Saxony					
	Pommritz		Spröda		Glesien	
Maturity group	Early	Medium-early	Early	Medium-early	Early	Medium-early
	220	230-250	220	230-250	220	230-250
Crop year 1995	13	15	12	15	7	8
Crop year 1996	7	8	-	-	7	8

[1]number of the tested varieties

3 Results and Discussion

Among the tested maize varieties from three locations no statistical influence of varieties could be established. The mean total phosphorus content of the 100 tested samples was 3.41 ± 0.51 g/kg DM, the phytate phosphorus content 2.63 ± 0.38 g/kg DM and the ratio phytate/total-P 77 ± 10.0 % and the phytase activity of the selected samples was < 50 Unit/ kg. These results are little higher than the values given in DLG feed tables (1973; total-P 3.2 g/kg DM), which include results by many authors. The determined values agree with the results by Deosthale (1979) who determined total-P with 3.30 g/ kg DM, phytate-P with 2.61 g/kg DM and the ratio phytate/total-P: 79 % using the same method as in the present study. Other authors described lower contents, e.g. Pointillart (1994; phytate-P: 1.7 - 2.2. g/kg DM); National Research Council of the USA (1994; total-P: 2.8 g/kg DM; phytate-P: 2.0 g/kg DM); Pierce et al. (1977; total-P: 2.7 g/kg DM; phytate-P: 2.3 g/kg DM). However, their percentages of phytate in total phosphorus agree with the values of this study. Underwood (1977) explained these variabilities by different soil types, genetic differences of the samples and the influences of season and maturity group. This last mentioned aspect could be proved by this analysis. Other reasons for deviations can be suspected in different methods of analyses as Most et al. (1993) assumed. In Table 4 below the mean values of total and phytate phosphorus are represented according to the maturity groups of the 27 tested varieties on two locations in 1995. As one can notice there is a significantly statistical influence of maturity groups on total and phytate phosphorus.

In the following table 5 the influence of the location is shown. It has effects on the total phosphorus and phytate phosphorus contents when the mean values from the three tested locations were compared.

Besides an influence of the crop year on total phosphorus, phytate phosphorus and on its portion in total phosphorus could be statistically determined. There was a big difference between the mean values ascertained for 1995 and 1996 (see Table 6). The reason was probably that there were big differences concerning the amount of precipitation and the time of dry and wet periods.

Table 4: Mean total phosphorus and phytate phosphorus contents of the maturity groups of grain maize samples (n=54) from the locations Pommritz and Spröda in 1995

Maturity group	Total phosphorus	Phytate phosphorus	Phytate phosphorus in total phosphorus
	(g/kg DM)		(%)
Early (n=24)	$3.00^{a} \pm 0.23$	$2.53^{a} \pm 0.31$	84 ± 7.4
Medium-early (n=30)	$3.33^{b} \pm 0.22$	$2.76^{b} \pm 0.33$	83 ± 9.6
Mean value	3.17 ± 0.28	2.65 ± 0.34	84 ± 8.6
p-value	***	**	0.65 *ns*

Table 5: Influences of locations on the total and phytate phosphorus contents of grain maize

Location	Total phosphorus		Phytate phosphorus		Phytate phosphorus	
	(g/kg DM)				(% in total phosphorus)	
Pommritz (n=43)	3.24^{a}	± 0.51	2.48^{a}	± 0.39	76	± 12
Glesien (n=30)	3.70^{b}	± 0.59	2.80^{b}	± 0.34	76	± 9
Spröda (n=27)	3.30^{ab}	± 0.38	2.60^{ab}	± 0.43	79	± 7
Mean value	3.41	± 0.57	2,63	± 0.38	77	± 10
p-value	**		**		*ns*	

Table 6: Mean total phosphorus and phytate phosphorus contents of the crop year 1995 and 1996

Crop year	Total phosphorus		Phytate phosphorus		Phytate phosphorus	
	(g/kg DM)				(% in total phosphorus)	
1995 (n = 70)	2.87^{a}	± 0.57	2.39^{a}	± 0.33	83^{b}	± 10
1996 (n = 30)	3.94^{b}	± 0.42	2.78^{b}	± 0.35	70^{a}	± 8
p-value	***		**		*	

The relation between total phosphorus and phytate phosphorus of all samples in both crop years (n=100) was a positive, significant correlation (Fig.1). The function of correlation means that the phytate phosphorus increases by 0.43 g/kg DM when the total phosphorus content rises by 1 g/kg DM.

Horvatic and Balint (1996) determined in their tests with three grain maize varieties from two crop years higher correlations (r = 0.94 for 1985; r = 0.80 for 1986). There are no specific data for grain maize so that further possibilities of comparing are not available.

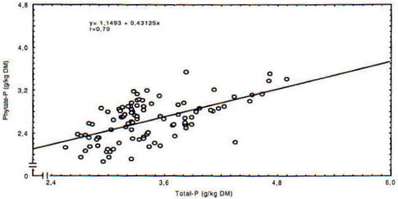

Figure 1: Correlation between total-P and phytate-P (g/kg DM) in grain maize

From the 15 maize varieties that were tested both in 1995 and 1996 six varieties were chosen to determine their phytase activities. All of them obtained phytase activities below 50 U/kg which is characteristic of maize and did not show any variability. So the analyses by Pointillart (1993 and 1994) as well as by Eeckhout and De Paepe (1997) could be proved by this study.

Gesamt- und Phytatphosphorgehalt in Körnermais *(Zea Mays)*

Zusammenfassung

In diese Untersuchung wurden 28 Körnermaissorten des Standortes Pommritz und 27 Körnermaissorten des Standortes Spröda des Erntejahres 1995 einbezogen, von denen 12 der frühen und 15 der mittelfrühen Reifegruppen zugehörten, wobei es das Ziel der vorliegenden Arbeit war, diese Sorten auf ihre Gesamt- und Phytatphosphorgehalte zu prüfen. 15 Körnermaissorten des Standortes Pommritz wurden ausgewählt, um sie in den Erntejahren 1995 und 1996 auch auf dem Standort Glesien zu testen. Es sollte analysiert werden, ob auftretende Variabilitäten der Gesamt- und Phytatphosphorgehalte bzw. der Phytaseaktivität sorten-, standort- oder witterungsbedingt sind.

Folgende Ergebnisse der vorliegenden Analyse lassen sich zusammenfassen:

1. Für die Körnermaissorten konnte über zwei Erntejahre kein statistisch signifikanter Sorteneinfluß auf den Gesamt- und Phytatphosphorgehalt nachgewiesen werden.

2. Ein statistisch signifikanter Standorteinfluß zweier Standorte wurde für den Gesamt- und Phytatphosphorgehalt über zwei Erntejahre festgestellt.

3. Für die Erntejahre wurde für drei Standorte ein statistisch signifikanter Standorteinfluß auf Gesamt- und Phytatphosphorgehalt sowie auf den prozentualen Anteil Phytatphosphor am Gesamtphosphor verzeichnet.

4. Für das Erntejahr 1995 wurden statistisch signifikante Unterschiede bezüglich des Gesamtphosphorgehaltes und des Phytatphosphorgehaltes zwischen den Sorten der frühen und mittelfrühen Reifegruppe auf den Standorten Pommritz und Spröda gesichert.

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